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TRANSLATION

A GYROSCOPIC DAMPER OF ANGULAR OSCILLATIONS

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A GYROSCOPIC DAMPER OF ANGULAR OSCILLATIONS

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A GYROSCOPIC DAMPER OF ANGULAR OSCILLATIONS

V. Yu. Torochkov

In practical applications the problem often arises of separating from the frequency spectrum its individual components by introducing filters of a definite construction into the measuring system. The damping process to be studied can separate the low-frequency components alone of the spectrum. The resistive force of a displaced body in a medium or in an electromagnetic field is commonly used in damping. This sort of damping can cut off a limited range of frequencies and depends on external conditions (e.g., temperature, pressure). A gyroscopic damper capable of damping angular oscillations in a broad frequency range can be practically free of the disadvantages pointed out.

Let a certain platform A (Fig. 1) oscillate about axis X. Let us take in the plane of the platform some fixed axis $\xi\xi$ in relation to which we will measure the rotational angle of the platform. For this purpose we will choose in the plane of the platform $\zeta\zeta$ rigidly connected with the platform and will designate the angle between the axes as α.

If we connect the platform with a gyroscope, i.e., consider the axis X is the rotational axis of the external ring then obviously the platform itself cannot rotate, but the momenta of the forces which previously caused it to rotate will be applied to the gyroscope (to the X axis). We will represent that force F is applied to the platform, then the momentum acting on axis X

$$M_X = Fl \sin \alpha.$$

If force F changes continually in size and direction, momentum M_X changes for this very reason and the platform performs chance oscillatory movements which must be damped by the gyroscopic system (Fig. 3).

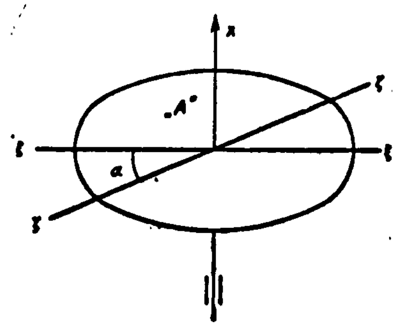

Fig. 1.

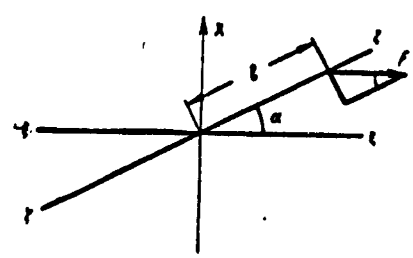

Fig. 2.

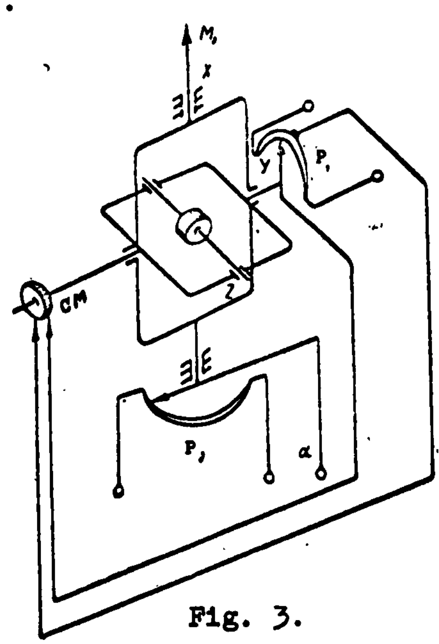

Fig. 3.

Momentum M_X acting on the rotational axis X of the exterior Cardan ring causes a precession with an angular velocity β around axis Y of the interior frame. The brush of potentiometer P_1 is rigidly connected to the Y axis and its signal is of course proportional to angle β, i.e., an integral of the angular velocity of the precession of the interior ring. The signal from the potentiometer enters the correcting motor CM. The momentum applied by the correcting motor to the interior ring causes a precession of the exterior ring about axis X with angular velocity α. Thus, momentum M_X applied to the rotational axis of the exterior ring after undergoing certain transformations finally causes the exterior ring to rotate about axis X. The rotation of axis X can be measured by potentiometer P_2. From what has been set forth it follows that angle α corresponds to a definite transformation of momentum M_X applied from without, i.e., the oscillatory angle of platform A.

Let us find the relationship between angle α and momentum M_X. We will examine the truncated equations of the gyroscope

$$\begin{aligned} H\dot{\beta} &= M_X \\ -H\dot{\alpha} &= M_Y \end{aligned} , \qquad (1)$$

where

$$\begin{aligned} M_X &= Fl \sin \alpha \\ M_Y &= k\beta \end{aligned} , \qquad (2)$$

and $\underline{k}$ is the coefficient of proportionality between the voltage on potentiometer P_1 and the momentum developed by correcting motor CM.

In the following we will examine small angles α, and consequently

$$\sin \alpha \approx \alpha$$

Let us differentiate the second equation of system (1) with regard to (2)

$$- H\ddot{\alpha} = k\dot{\beta}. \tag{3}$$

But from the first equation of system (1)

$$\dot{\beta} = \frac{M_x}{H},$$

or

$$\dot{\beta} = \frac{Fl}{H}\alpha.$$

After substituting into (3) we have

$$H\ddot{\alpha} + \frac{kFl}{H}\alpha = 0.$$

Let us designate

$$\frac{klF}{H^2} = m^2,$$

then

$$\ddot{\alpha} + m^2\alpha = 0. \tag{4}$$

The roots of this equation should be real, since we will obtain nondamping harmonic oscillations if the roots are imaginary. To obtain real roots it is necessary that $m^2 < 0$. This is possible if $\underline{k} < 0$. In this connection we have

$$\ddot{\alpha} - m^2\alpha = 0. \tag{4'}$$

This equation has as its general solution

$$\alpha = c_1e^{mt} + c_2e^{-mt}. \tag{5}$$

The boundary conditions are

$$\alpha(0) = \alpha_0,$$
$$\alpha(\infty) = 0.$$

Consequently, $c_1 = 0$ and the particular solution (4') will be

$$\alpha = \alpha_0 e^{\frac{-kFl}{H}t} \tag{6}$$

The equation obtained connects the oscillations of platform fixed to the gyroscope with the oscillations of the gyroscope itself. From this equation it follows that the gyroscope actually obliterates the primary oscillations which enter its input.

We will designate

$$\frac{H}{\sqrt{kFI}} = T, \quad (7)$$

then

$$\alpha = \alpha_0 e^{-\frac{t}{T}}. \quad (6')$$

It is obvious that the larger T, the greater the degree of damping and the lower the frequencies filtered out. When $T \to \infty$ the gyroscope will pass only those oscillations the period of which also tends toward infinity. When $T \to 0$ we get the reverse picture; the gyroscope will pass almost all the primary oscillations.

Thus the gyroscopically based damper can have a damping coefficient variable within very broad limits. The degree of damping, as follows from (7), depends on two parameters: the kinetic momentum H and the coefficient of proportionality k. If H is difficult to change in a given gyroscope then k is easily changeable by changing the voltage applied to potentiometer P_1.

REFERENCE

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